

Seismic Characterization of Tunnel Boring Machine Activity Near Boston, MA, USA

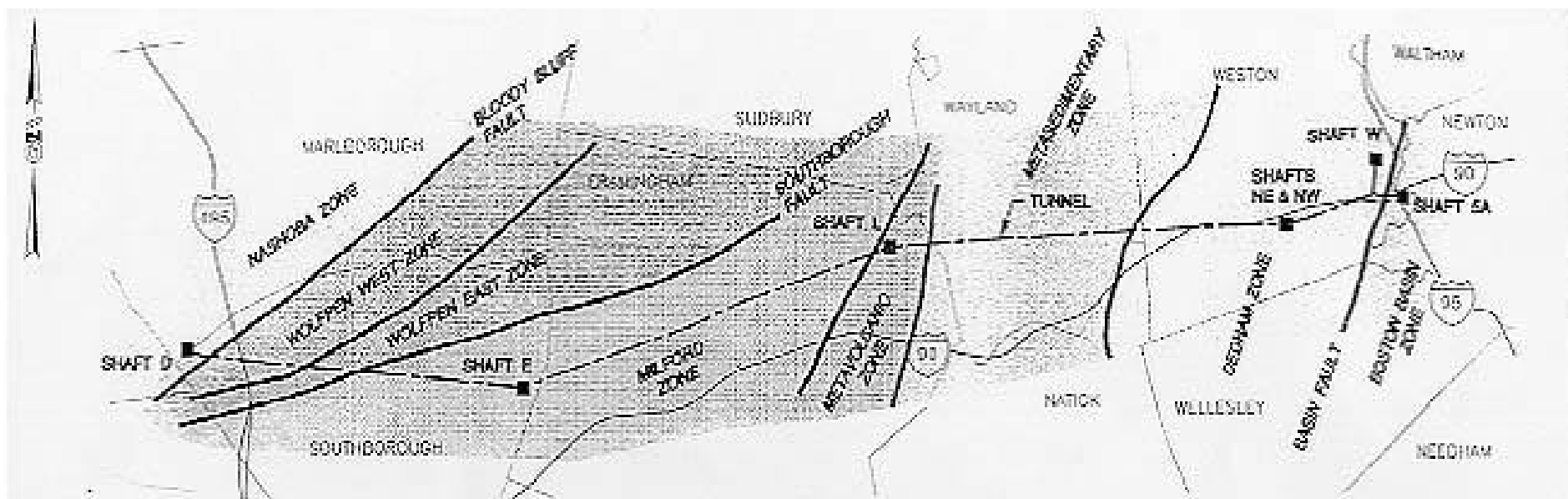
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Introduction

To characterize the seismic wave field associated with hard rock tunneling and associated activities, 14 seismic stations were deployed in and near a tunnel being bored by a tunnel boring machine (TBM) for a water project near Boston. The 5.15 m tunnel is being bored through granitic and metamorphic rocks at a depth of about 125 m. Seismographs were deployed for about 1 week during August of 1999, and recorded about 40 hours of TBM activity. The deployment consisted of both short-period and broadband instruments, and an array of aperture 60 m was deployed at the second-closest broadband site. During one 8-hour work shift, a short-period and broadband sensor pair were deployed inside the tunnel, about 35 m behind the TBM.

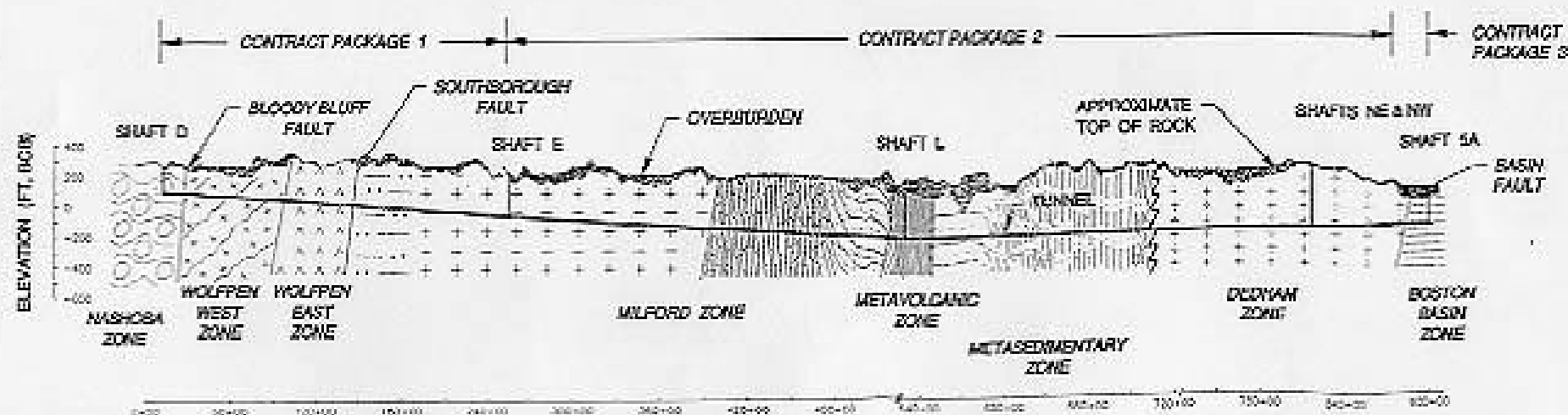




PLAN SCALE: 1" = 8,000'

0 4,000 8,000 16,000

PLAN



VERTICAL SCALE: 1" = 800'

0 400 800 1,600

0 4,000 8,000 16,000

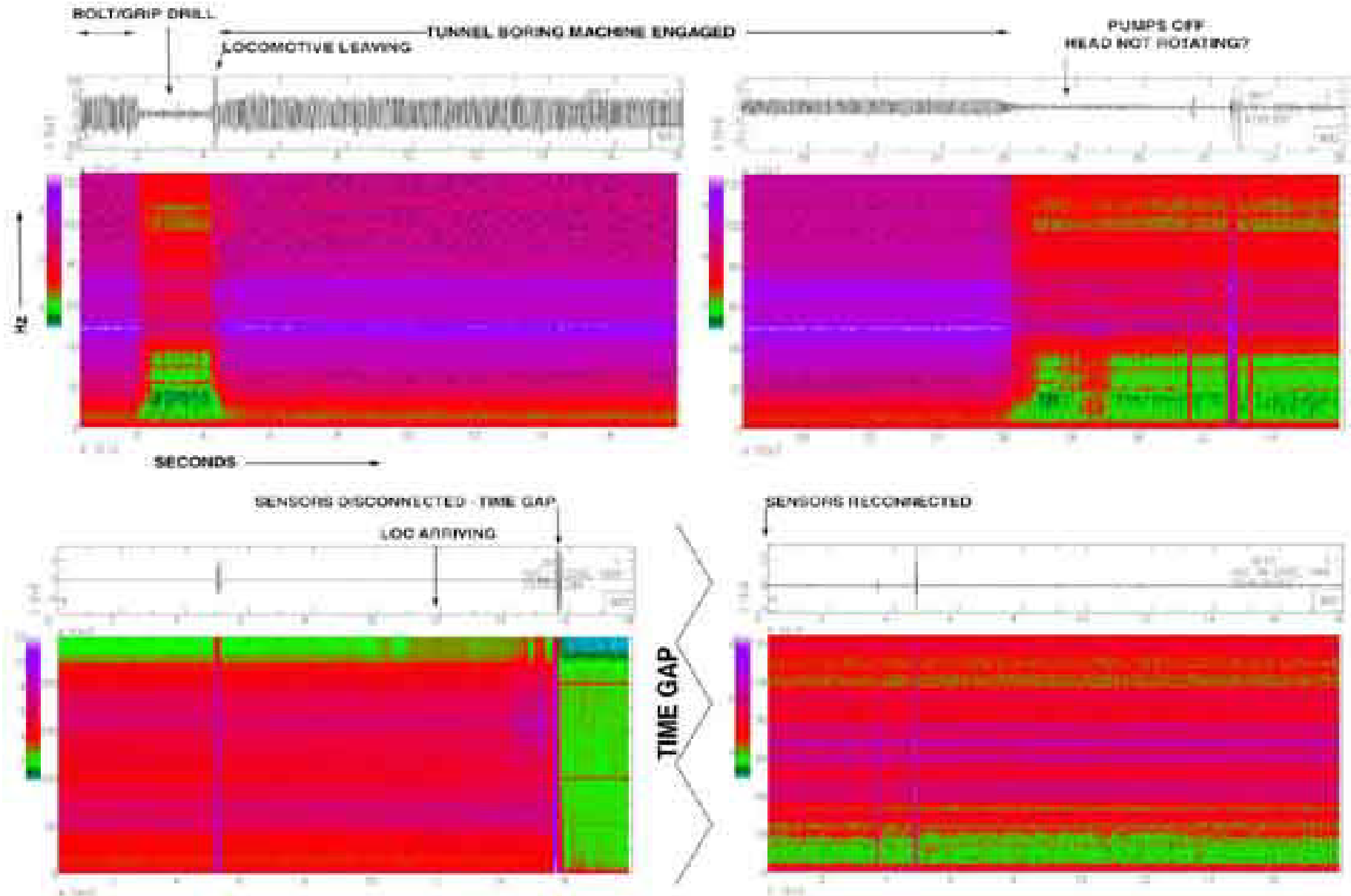
PROFILE

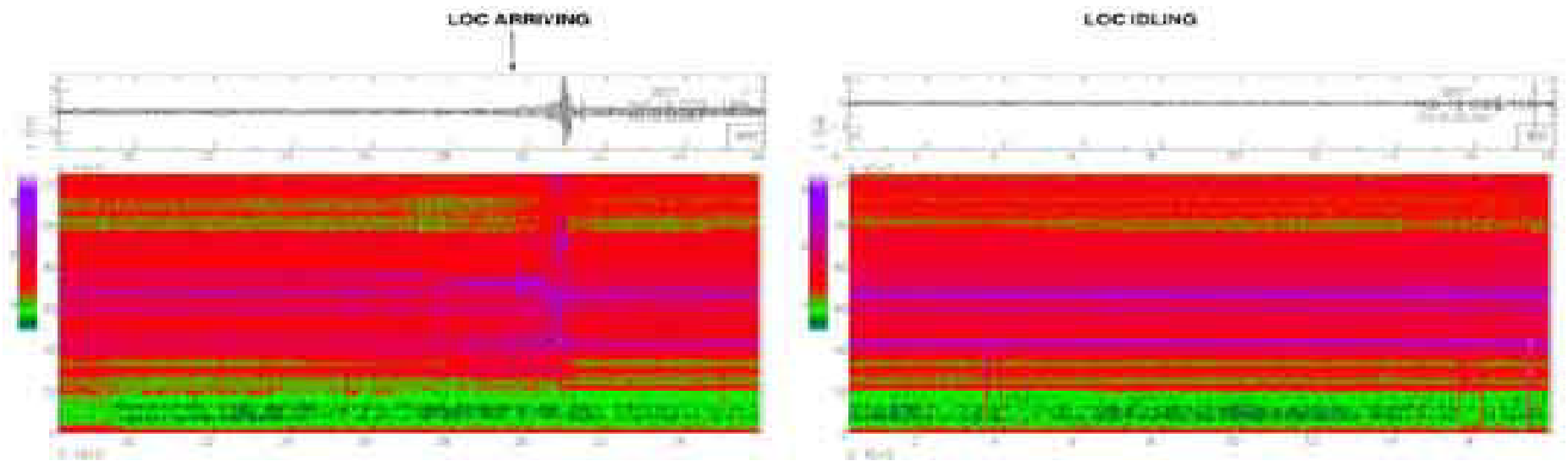
NOTE:

1. THE LOCATION OF CONTACTS BETWEEN LITHOLOGIC ZONES AND FAULTS ON THE PROFILE ARE APPROXIMATE.
2. THE CHARACTERISTICS OF NAMED FAULTS ARE DESCRIBED IN REPORT TEXTS.

Spectrograms

Spectrograms (spectra versus time) for the vertical component of an L-4C (1hz) sensor located in the tunnel at site TNL. Each spectrogram is a half hour long. Sequential spectrograms for 3 hours and 45 minutes of continuous seismic data are presented here by groups of two. Time increases from left to right in each spectrogram, and each successive group from top to bottom follows the one preceding it.





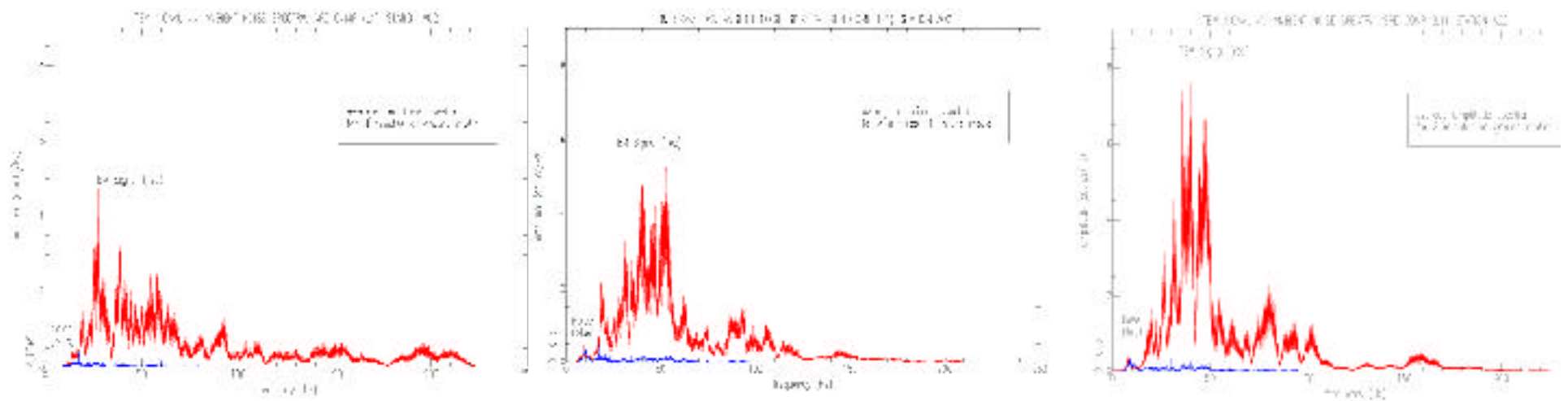
Signal and Noise Spectra at AQ2 and AQ9

Station AQ2

V

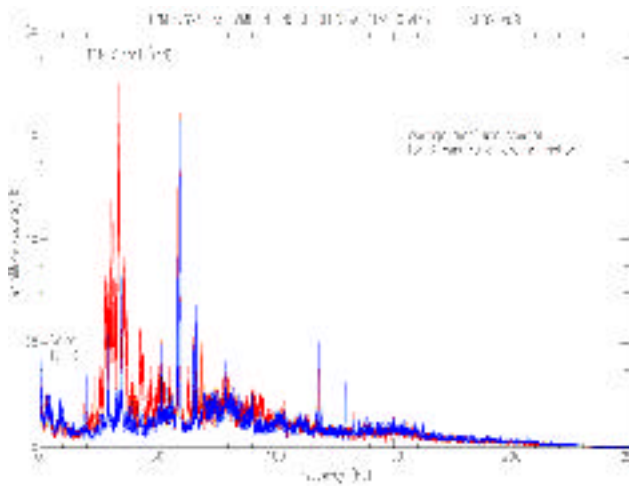
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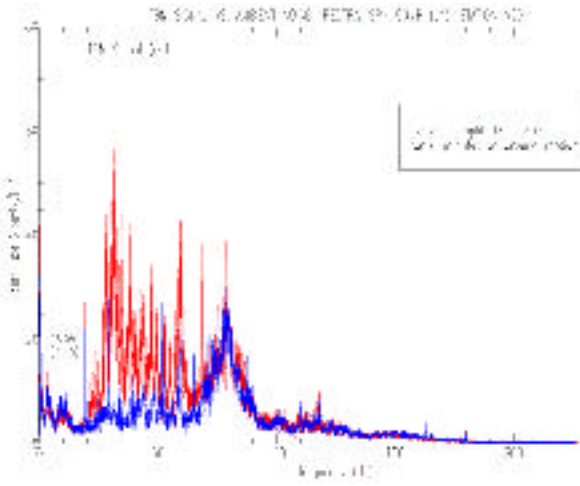


Station QA9

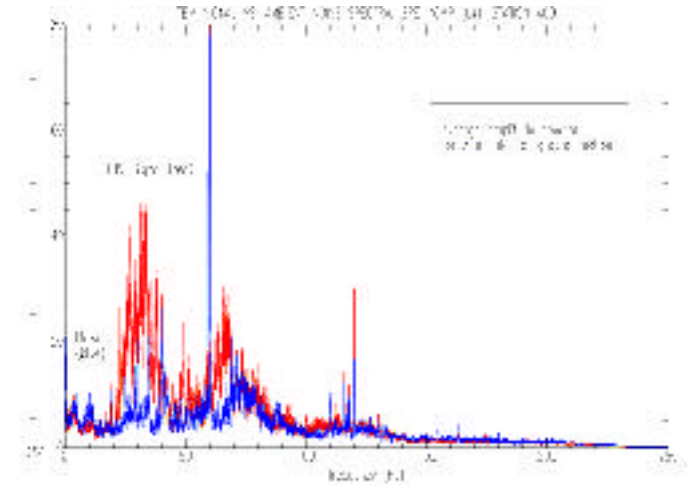
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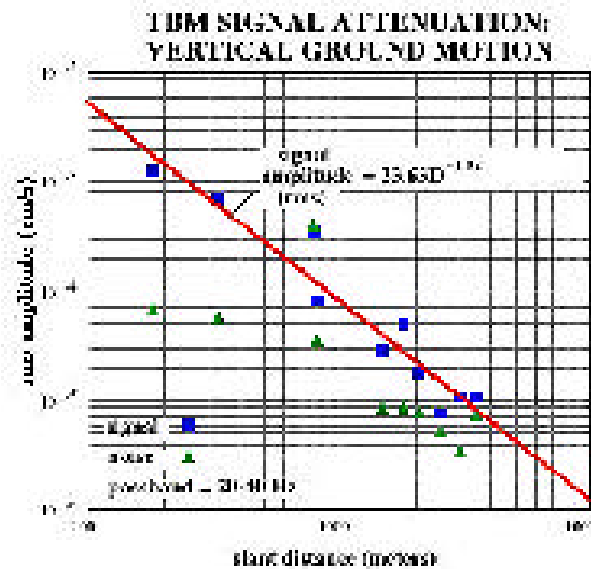


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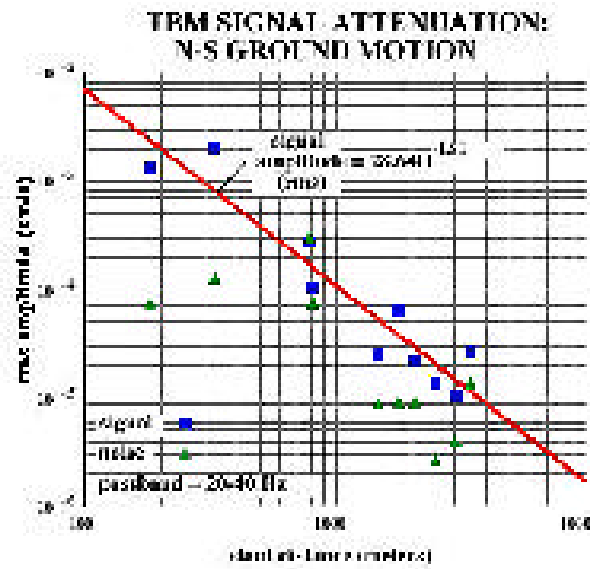


TBM Signal Attenuation

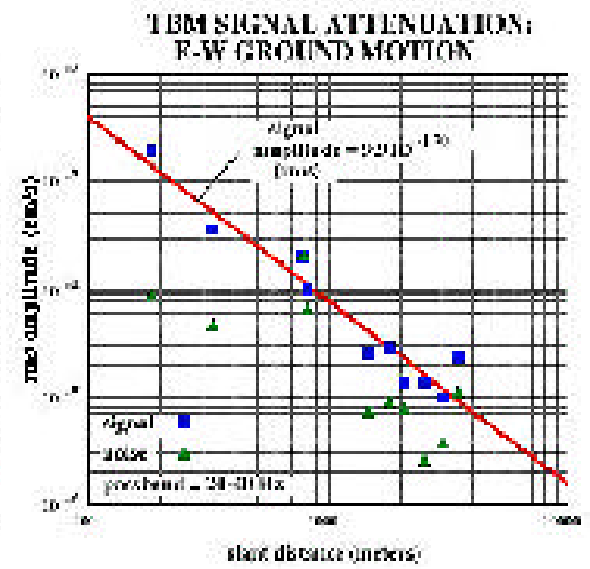
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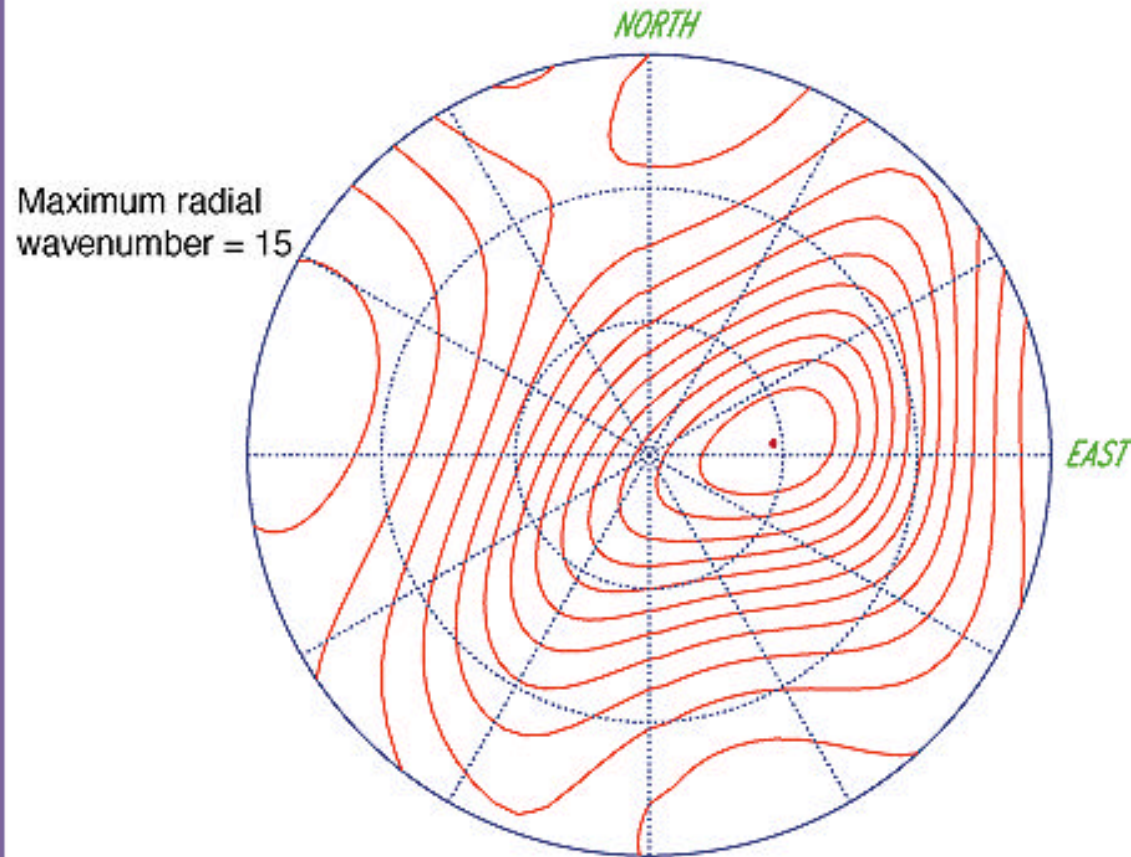
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F-K Results



5 station array , TBM data bandpassed from 20 to 50 Hz

F-K back-azimuth = 85° , wavenumber = 4.8

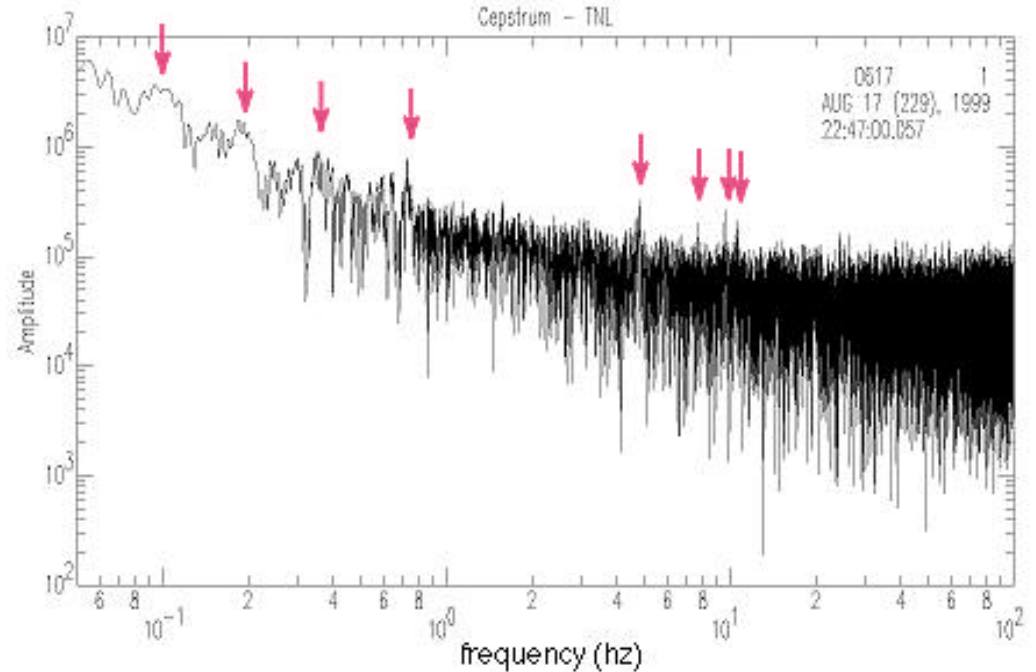
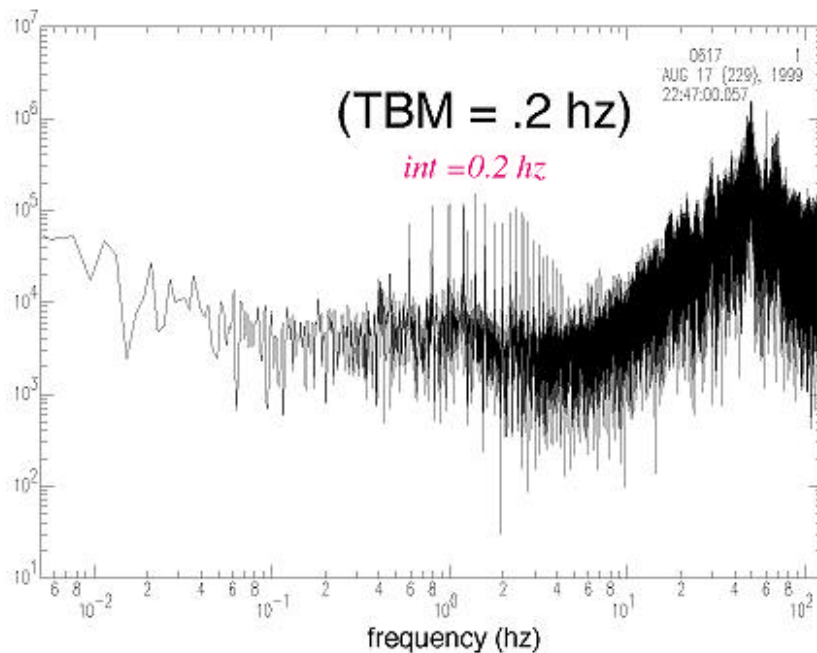
True back-azimuth = 78.0°

Acoustic Resonances in the Tunnel?

Organ pipe modes in tunnel: $nv/4l$; $n = 1, 3, 5, \dots$

Interval between modes: $v/2l = 0.025$ Hz

(v = sound speed in air, .3km/s; l = distance from head of tunnel to shaft = 6.06 km)



Conclusions

TBM activity can be seen to distances of about 3.0 kilometers at the MetroWest water supply tunnel 10 miles west of Boston, MA. Similar results were obtained in earlier studies in this region. In quieter settings, other TBMs have been seen seismically at 5.5 km (Yucca MTN, NV) and 20 km (Calaveras, CA).

The TBM signal is wideband and peaked between frequencies of 20 - 80 Hz. Stacking, either in frequency or time does not appear to enhance signal to noise ratios. We observe changes in spectral content associated with tunnel related activities, including the arrival and departure of the service locomotive. TBM signal attenuation was measured for over a passband of 20-40 Hz, and is observed to decay as approximately the inverse of the squared distance between the TBM and the receivers. This is consistent with other TBM studies.

Further work will entail filtering the raw data using different passbands to try to enhance the signal out to further distances, detailed comparisons of tunnel and surface data, array analysis to determine TBM location, and analysis of spectral peaks associated with tunnel operations.

For more information, view the "Technical Documents" section at <http://www.ees3.lanl.gov>.